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Scientific Intelligence Report

Soviet Research and Development on the Desalting of Water

OSI-SR/65-19
4 June 1965

Office of Scientific Intelligence

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SOVIET RESEARCH AND DEVELOPMENT ON THE DESALTING OF WATER

Project Officer

[redacted] 25X1A

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CENTRAL INTELLIGENCE AGENCY

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PREFACE

Desalination generally means the conversion of salt or brackish water to fresh water suitable for human consumption or agricultural and industrial use. Seven-tenths of the earth's surface is covered by water too salty for such purposes.

The basic consideration in desalination is the production of fresh water at the lowest possible cost. Energy in some controllable form is required for the conversion and it is the cost of this energy that must be kept as low as possible. Different geographic areas present different water conversion problems. Each area must be examined on the basis of its specific requirements and a process selected to fit the particular area. As a result, research takes place on a wide spectrum of methods and processes. The potential of utilizing atomic reactors as competitive sources of energy is stimulating the USSR to follow the lead of the United States in developing desalination processes powered by nuclear reactors.

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SOVIET RESEARCH AND DEVELOPMENT ON THE DESALTING OF WATER

PROBLEM

To assess Soviet accomplishments on methods for the desalting of water.

CONCLUSIONS

1. The Soviet desalination development program is smaller in size, effort, and capital investment than the program of the United States and appears to be 3 to 5 years behind current US developments. Although the Soviets have competent scientists doing excellent research in desalination, their accomplishments in terms of pilot plants, hardware, and development of economical processes have not been significant. The lack of apparent, significant Soviet accomplishments may be due to their primary concern with the removal of salts from brackish or low-salt-content water. This is a less difficult problem than the removal of salts from sea water, which is the major concern of related US technology.

2. Pure water requirements for steam-powered electrical generating plants and for the chemical industry provided the original impetus for Soviet desalination research. More recently, there has been a growing demand for industrially usable water in a few rapidly developing areas in the Soviet Union. This has been responsible for increasing Soviet research efforts to develop economically feasible methods for desalting brackish waters.

3. The processes of freezing, reverse osmosis, hydration, and biological treatment have been given only limited study in the USSR, but ion exchange and electrodialysis processes have received considerable Soviet research attention. An electrodialysis plant of unknown size is reported in operation in Alma Ata. The prospect of using nuclear power as a source of thermal energy has rejuvenated Soviet interest in distillation as a large-scale method of salt removal and has diverted interest from other methods. Research on multieffect evaporation (distillation) with film and drop condensation, and on prevention of scale, is now being carried out on a level comparable with that of Western research. Successful research has resulted in three medium-size, fossil-fuel-fired distillation plants in operation at Shevchenko, Baku, and Krasnovodsk.

4. Future Soviet desalination development will continue to emphasize distillation, electrodialysis, and ion exchange processes, with concentration of effort on the use of nuclear reactors as sources of electric power and of thermal energy for saline water distillation. Considerable

technical assistance is expected from the US as a result of the two-year US-USSR joint agreement on cooperation in nuclear desalination scheduled to start in 1965. The USSR plans to build at Shevchenko on the Caspian Sea a 1,000-megawatt thermal, fast nuclear reactor coupled to a desalination plant; the plant is to have an eventual fresh water output of up to 50 million gallons per day. However, this reactor represents a 200-fold scale-up of present Soviet reactor technology, and it is likely that there will be slippage in the projected completion date of 1969.

SUMMARY

The Soviet desalination program was small and slow moving up to 1962 when it was transferred from the control of the State Committee for Chemistry to the State Committee for Utilization of Atomic Energy. The transfer reflects Soviet efforts to elevate the national status of the program and the intention to develop the use of nuclear power sources for desalination purposes.

Soviet work on distillation appears to have concentrated on prevention of scale formation on heat transfer surfaces, a problem intimately associated with distillation. They have had some success in preventing scale build-up through use of chemical and ion exchange treatment of feed water, and crystal seeding of water in the evaporator. The Soviets realize that present distillation practices is too expensive in terms of fuel consumption to be utilized in the USSR on a large scale. However, they believe that if scale formation can be controlled sufficiently, distillation is the only method sufficiently developed to be adaptable to large-scale operation. Present Soviet plans contemplate the use of dual-purpose fast nuclear reactors which will supply electrical energy as well as thermal energy required for distillation.

In the USSR, lime is being used increasingly to precipitate calcium and magnesium salts from saline or low-salt-content waters prior to distillation. A thermochemical refinement of this process, a combination of precipitation and ion exchange, also is finding favor with the Soviets. Initially it was developed by them as a method of softening boiler feed water but it is now being used to pretreat saline water fed directly to evaporators in the distillation process. The method is designed primarily to control scale formation.

The Soviets have made satisfactory use of chemical methods for desalting—ion exchange being the principal one used. Ion exchange resins now being used in the USSR are quite similar in function to those made in the West but are not as efficient and apparently are in short supply. Soviet developments in ion exchange resin technology have not shown any recent major gains.

Electrodialysis holds great interest and potential for the Soviets. They seem convinced that the method represents an economical approach to solving their immediate problem of removal of salts from brackish water and are aware that extensive Western research has shown the method to be very satisfactory for low-salt-content water. Using published Soviet scientific literature as a measure, more Soviet research and development

work has been done on both ion exchange and electrodialysis than on all other methods combined. The Soviets appear to be considering the more extensive use of electrodialysis for removing salts from boiler feed water used by electric power plants. Extraction, crystal hydrate, reverse osmosis, ion osmotic, and biological desalting methods are in very early stages of research in the USSR.

Actual operating Soviet desalting plants include: a 1.5-million-gallon-per-day fossil-fuel-fired distillation plant at Shevchenko utilizing a seeding method to reduce scale; a 0.9- to 2.25-million-gallon-per-day distillation plant at Baku utilizing thermochemical treatment of feed water; and a 0.5-million-gallon-per-day distillation plant in Krasnovodsk believed to have been operating since 1946 in conjunction with an electric power station. In addition, an electrodialysis plant of unknown size has been reported in Alma Ata.

Of considerable significance is the ambitious plan of the Soviets to utilize a fast nuclear reactor of 1,000-megawatt thermal capacity, to be built at Shevchenko, to provide both electricity for general use and steam for desalting water. This reactor represents a 200-fold scale-up from their BR-5 research reactor. It will be several years before this becomes a reality.

DISCUSSION

DISTILLATION (EVAPORATION)

There has been a notable lack of Soviet reporting on any improved methods for distillation over the past eight years.[1] The Soviets consider distillation the only process that seems likely to be suited for large-scale use in the manufacture of fresh water. While small-scale distillation units are in operation, large-scale use is probably awaiting a considerably cheaper source of thermal energy, presumably nuclear energy.

Soviet capabilities in the theoretical aspects of distillation research compare favorably with those of the West, but in practice, the USSR is at least several years behind.[2] Significantly, in Soviet distillation development there has been little attention to modern flash distillation systems.[3]

In July 1964, at a US-USSR exchange meeting on desalination in Washington, D. C., A. I. Churin reported on the large distillation unit in operation in Shevchenko, producing 1.5 million gallons of water per day (see photograph.) The unit is now operating on petroleum fuel.[4] However, a nuclear fast reactor with a capacity of over 1,000 megawatts thermal is under construction at Shevchenko. The Soviets have concluded that the use of desalted water for human consumption and agricultural purposes will only be economically feasible with the use of large nuclear reactors that produce electricity as well as thermal energy for desalination. This corresponds with Western conclusions that, in general, dual-purpose (electricity and low-pressure steam) nuclear energy plants offer advantages over single-purpose plants. The advantage lies in the low-pressure steam needed for distillation which can

be obtained less expensively than from single-purpose, low-pressure steam plants.

At the Washington meeting, V. A. Klyachko reported that the potential use of heat from nuclear reactors has recently prompted a tremendous effort in the USSR to develop methods of salt water distillation including multieffect evaporation plants.[5] Closely associated with this development program is an intensive investigation of scale prevention. The Soviets believe strongly that if distillation is to become economically feasible, the problem of scale formation must be solved.

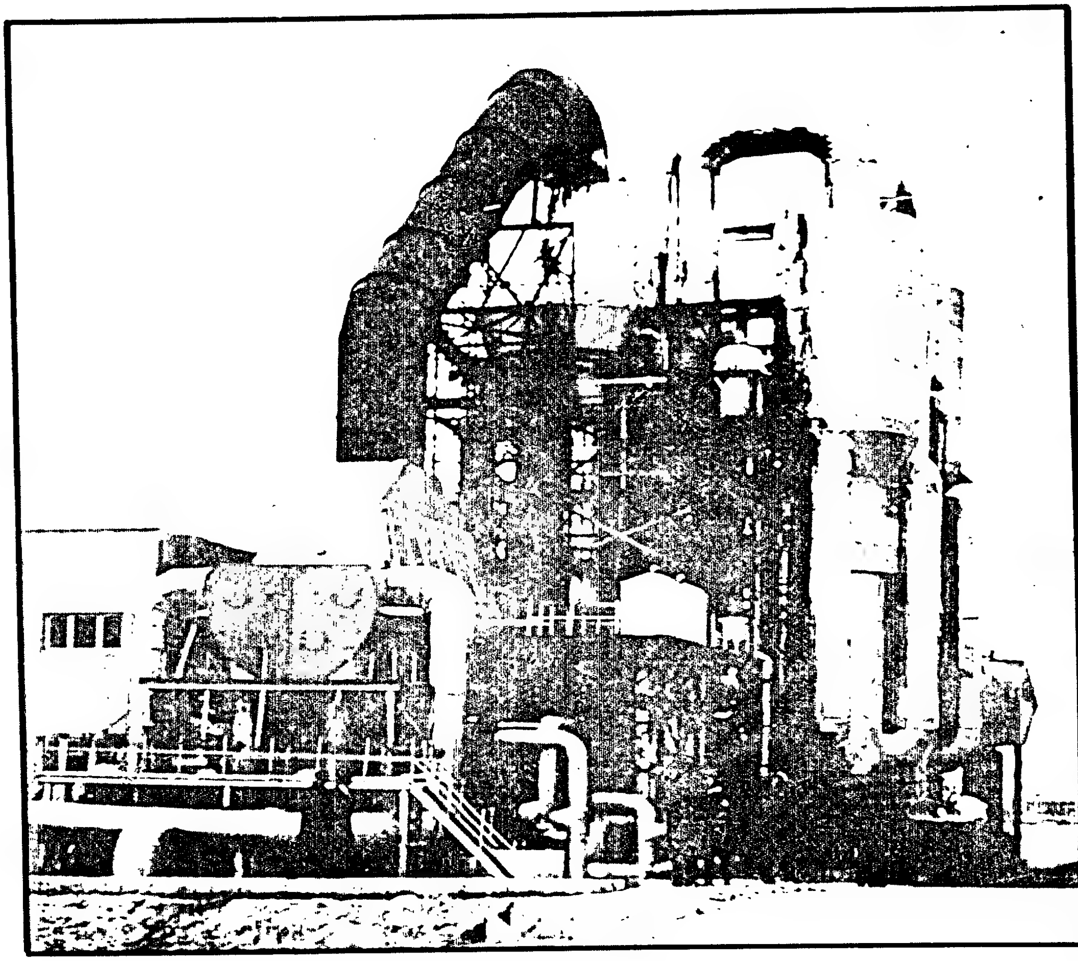
A great deal of fundamental research has been done in the USSR on scale formation and its prevention. Projects have included study of the behavior and solubilities of salts in steam and their removal from steam; behavior of sodium and potassium sulfates, chlorides, and mixtures of these at various temperatures up to 800° C; and the solubility of calcium sulfate in sodium chloride at various temperatures. Among the methods for prevention of scale formation being investigated are crystal seeding, magnetic-field techniques, and thermochemical water softening.

Crystal Seeding Method for Scale Prevention

The USSR has successfully used this method. It consists of introducing finely dispersed precipitated scale (or chalk) slurry into the evaporator where it is recirculated.[6] Here the precipitated scale acts as a seed to facilitate crystallization of sea water salts, thus protecting the heat transfer surfaces from formation of scale. The method is considered economically attractive for no special equipment is required except one unit in the system for seed retention. No additional seed need be added during the operation. In addition, the seeding material is neither difficult to obtain nor costly and its use does not add appreciably to the cost of the distillation.[7] The distillation plant at Shevchenko uses seeding with natural chalk of 30- to 100-micron particle size.[8 9]

Magnetic-Field Method for Scale Prevention

This method of treatment has been fairly successful in the USSR in treating boiler feed water, but it reduces scale formation only very slightly in an evaporator.[10] The Soviets have claimed that the method decreases the tendency for scale to form, and makes the scale which does form have the appearance of loose flakes, very responsive to easy removal.[11-15] The system has been installed in a plant in Kazakhstan and in the Dmitrievsk wood-processing plant. Problems pertaining to magnetic treatment of water are being studied by the All-Union Heat Technology Institute, the Kharkov Engineering and Economics Institute, the Ministry of the River Fleet RSFSR, the Ural Power Engineering Trust for the Ferrous Metallurgy Industry, the Chemical Service of the Donets Basin Regional Electric Power Administration, and other organizations. Magnetic-field equipment developed by the Alma Ata Heavy Machine Building Plant for the treatment of hard water was mounted inside the boiler-feed water pipe of a model DKU-65-B steam plant. It was claimed that after 3 months of operation no scale was detected on the walls of



Distillation Plant at Schevchenko

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pipes; however, the collectors contained a layer of soft precipitate that was removed easily.

Thermochemical Method for Scale Prevention

For several years, work has been conducted at the Institute of Petroleum Chemistry under the direction of I. Makinsky on the development of a "thermochemical method" for "deep softening"* of sea water.[16 17] This method is essentially a combination of precipitation and ion exchange. Precipitation is employed chiefly to remove magnesium and calcium salts. Very simply, the sea water is treated with calcium hydroxide (lime) to raise the p^H to 10.5; at this p^H magnesium hydroxide and calcium carbonate are precipitated. Subsequent heating in a "thermochemical softener" to a temperature corresponding to that for minimum solubility of calcium sulfate causes some of the calcium sulfate to crystallize out of solution. The water, with magnesium salts and part of the calcium sulfate removed, is fed to a cation ion exchanger for removal of remaining residual salts before going to the evaporator. Although the method initially was developed for softening boiler feed water, it also has been used in the USSR for pretreating water fed to salt water evaporators.

A distillation plant providing boiler feed water for the Severnaya State Regional Electric Power Station north of Baku has been operating since 1963 without formation of scale, using the thermochemical method of water treatment.[6 18] The output is 0.9 to 2.25 million gallons per day from a direct flow, four-effect vertical evaporator. The heat source is a boiler supplying super-heated water.[5 7 9 19] In this application, the cation exchange filter are regenerated with waste water from the evaporators containing a 15 percent solution of sodium chloride and sodium sulfate.[20]

*"Deep softening" presumably means the nearly complete removal of the calcium, magnesium, and other ions.

Other Methods of Scale Prevention

The use of peptizing agents and water repellents on heat transfer surfaces has also been investigated. The Soviets claim that the periodic spraying of a suspension of copper oleate or a mixture of several aliphatic amines with nitroparaffin into the steam flow will produce a water repellent film on heat transfer surfaces. This film controls the formation of condensation droplets with a significant increase in heat transfer. The Soviets have reported increases in the heat transfer coefficient of 70 to 120 percent. Heat transfer by intermediate agents (such as paraffin of "Dowtherm") also is being evaluated using long-tube, vertical heat exchangers.

CHEMICAL METHODS OF DESALTING

The desalting of natural waters by means of ion exchange agents is regarded as feasible and expedient in the USSR when the total content of sulfate, chloride, and nitrate ions in the water is not too high. An intensive effort appears to be underway in the Soviet Union in the field of ion exchange.[21] Special emphasis has been placed on the synthesis of new ion

exchange resins as well as on increasing the availability of the present resins for large-scale use. Generally, good research on ion exchange resins is being done by A. B. Pashkov and V. S. Titov at the Scientific Research Institute of Plastics and by other investigators at the All-Union Scientific Research Institute of Water Supply, Sewerage, Hydraulic Structure, and Engineering Hydrogeology (VODGEO). The resins now being used are quite similar to those used in the US and include amino-formaldehyde resins (urea-formaldehyde resins), phenolaldehyde resins, and polystyrene sulfonic acids. They do not seem to represent any major gains in ion exchange technology. Considerable effort also has been devoted to the use of sulfonated coal as a comparatively cheap replacement for the more expensive synthetic resins.[23] The rather low exchange capacity of sulfonated coal, however, has proved to be a serious drawback.

Until recently, the principal application for ion exchange resins in the USSR has been in water purification for use in high-pressure turbines that generate electric power. The Soviets have used them on waters of very low salinity where the process is one of demineralization rather than of desalination. The Soviets report that 10 electric power generating installations have been ion exchange resins for boiler water treatment for the past several years. Additional water-treatment installations are planned but the Soviets have stated that these plans have been seriously hampered by an inadequate supply of ion exchange resins.[22]

Desalination using ion exchange resins has been undertaken at a number of localities in Kazakhstan and the Ukraine, but the extent to which the technique actually has been applied is unknown. An ion exchange desalination unit designed by the All-Union Scientific Research Institute of Hydrotechnical and Sanitary-Technical Construction produces about 8,000 gallons of water per day at a "virgin land" facility in Kustanai, Kazak SSR, for $9.50 per 1,000 gallons. US distillation methods produce drinking water from sea water at a cost of about $0.90 to $1.25 per 1,000 gallons and there are prospects of reducing this cost to $0.60 per 1,000 gallons. Water from wells in most US locations costs only about $0.15 per 1,000 gallons.

A small-capacity ion exchange installation for the thorough desalination of water has been developed at the Scientific Research Institute of the State Committee on Radioelectronics. This unit, designated IGOM-50, is characterized by its compact design and automatic operation. This would indicate a Soviet interest in building increasingly practical operating units for industrial use.

Research also is being conducted on liquid ion exchangers that are insoluable in water and on hard ion exchangers especially adapted for sea water treatment by A. B. Pashkov, Ye. B. Trostyanskaya, B. N. Laskorin, and others.[5] A theory for evaluating ion exchange filters has been developed by F. G. Prokhorov, and K. A. Yankovskiy. Filters have been designed with a stationary layer of ion exchanger by A. M. Mamet, and S. M. Gurvich for direct flow and reflux cationization. Research is being conducted by N. S. Lebedeva and A. B. Zlotnikov on filters for water deionization, which have a suspended layer to provide continuous circulation of the ion exchanger.

ELECTRODIALYSIS

The Soviets believe, as do US specialists, that electrodialysis used with ion exchange membranes promises to be an efficient method for converting brackish water. Basic Soviet research in this area has included work on selective ion exchange membranes and their properties, the hydraulics of the filter press, types of electrodialyzers, and anode materials. The important scientists in this area are listed in appendix B. The Soviets have utilized two types of ion exchange membranes, the heterogeneous and the homogeneous types.[24-26] In the heterogeneous type, finely-ground commercial Soviet cation exchange resins (e.g., KU-2 or SDU-3) and anion exchangers (e.g., AV-16) are bound in a matrix of polyethylene or synthetic rubber and reinforced with screen of silk, capron (polycaprolactam fiber, or chlorinated polyvinyl chloride. These compositions are pressed into sheets of heterogeneous membrane up to 1,470 by 470 millimeters (58 by 19 inches) in size. Homogeneous membranes are made of condensation type and graft types of polymers. At the Institute of Chemistry of the Academy of Sciences of the Kazkh SSR, N. L. Lyubman and F. T. Shostak have developed a new type of membrane of cross-linked active polymers having linear macromolecules of inert thermoplastic polymer intertwined in their lattice. Membranes of the anion permeable type are produced by mixing polyethylene with polyethylene-polyamine and dichloroethane and then autoclaving for 60 minutes at 120° C. Anodes of platinum-plated titanium (having a micron-thick layer of platinum) and graphite are used with these membranes.

The Soviets made what may have been a "first" use of an electrodialysis unit in 1958 on the steamship Tula to provide fresh water for onboard service. The Tula is a ship of about 5,000-ton capacity operated by the Black Sea Steamship Company. The unit, which had a capacity of 3,000 gallons per day, operated for about 3 months before failure.[27-30] The salinity of the Black Sea water was about 21,000 parts per million (2.1 percent) and the salinity of the purified water was 320 parts per million. Power consumption is claimed to have been 46.8 kilowatt hours per cubic meter of water produced. While the cost of electricity on board the Tula is unknown, if a cost of one cent per kilowatt hour is assumed (which is higher in cost than electricity from an efficient, land-based generator), the cost of converting water on the Tula would have been about $1.77 per 1,000 gallons. This is a comparatively high cost for water conversion.

Generally, Soviet electrodialysis units are small, having a capacity of 3,000 gallons per day and operating with high electric power requirements of 50 to 80 kilowatt hours per 1,000 gallons of water.[31 32] The water produced has a salt content of 500 to 1,000 parts per millions which is acceptable for drinking and irrigation purposes. The salt water used has an initial salt content ranging from 2,000 to 10,000 parts per million.[35] Multichamber cells are used, equipped with diaphragms developed by the Moscow Aviation Technological Institute that contain 65 percent of type SDV-3 resin and 80 percent anion exchange resin of an EDE-10P. The output of such cells is claimed to be between 3.2 liters and 7 liters per square meter of diaphragm surface per hour, depending on the separation between diaphragms. Unconfirmed reports indicate that a 1.5-million-gallon-per-day unit with power consumption of 20 kilowatt hours per 1,000 gallons

of water may be in operation somewhere in the USSR but no details are available.[33 34]

Work on the development of electrodialysis methods to be used for desalination of Black Sea water has been conducted by O. S. Lenchevskiy of VODGEO in collaboration with Ye. B. Trostyanskaya of the Moscow Institute of Chemical Technology imeni Mendeleyev, V.S. Titov of the Scientific Research Institute of Plastics and, M. A. Orzherovskiy of the Black Sea Steamship Company. The USSR may soon choose a place on the northern coast of the Black Sea for the location of an electrodialysis plant.[36] Along this coast the salinity of surface water is rather low—less than 1.7 percent compared with about 3.5 percent for ocean water. The maximum salinity of the Black Sea water is 2.1 percent. This is an area of the USSR in which electrical power is relatively abundant.

Another electrodialysis unit located at the Novo-Ufimskiy Oil Refinery has been reported to be operational.[37] The addition of new types of horizontal electro-dehydrators to the existing 12 vertical electro-dehydrators on this unit is reported to have raised its output to 1.6 million gallons per day of water having a low chloride content of only 77 parts per million.

In 1964, the Soviets reported that they had begun the construction of experimental, industrial-type desalination units. These units reportedly have an output of 30,000 gallons per day each and employ heterogeneous reinforced ion exchange membranes manufactured by the Shchekinskiy Chemical Combine.[5] At the same time, it was claimed that the "planning and construction" were in progress for larger conversion plants with capacities of 220,000 gallons per day and for mobile plants of 3,000- to 20,000-gallons-per-day capacity.[7] No further details are available on such units.

OTHER METHODS OF DESALTING

The study of freezing, hydration, reverse osmosis, dialysis, solvent extraction, and biological methods for desalination are in very early stages in the USSR.[3] The Soviets have done laboratory experiments on a hydration and freezing process for desalination using propane and "Freon" as hydrate formers and butane as a secondary refrigerant, but they have had difficulty in getting the process to work. Their work appears to have been based on published Western research. The scale of Soviet experimental work in these areas does not compare in magnitude with Western work.[18 38]

FUTURE PLANS FOR NUCLEAR DESALINATION

The Soviet fast reactor BN-350, being constructed at Shevchenko, is planned to go critical in 1968 and to be utilized in production of water in 1969.[39] Electrical power output was originally reported to be 350 megawatts. This has now been cut back to 150 megawatts and the extra steam will be used for desalination. The reactor will have a thermal power of 1,000 megawatts. This will represent a 200-fold scale-up over the Soviet BR-5 research reactor. Prior to the startup of the reactor, the major components will be tested in the BR-60 reactor, which is to be constructed for this purpose in 1965-66.[40-42] Until the reactor becomes

operational, fossil-fueled boilers will be used to operate the desalination plant at this location, after which the fossil-fueled boilers will be maintained on a stand-by basis.[7]

The following time schedule and desalination program is planned for Shevchenko: 10,000,000 gallons per day late in 1966 or early 1967; 20,000,000 gallons per day late in 1967; and eventually to 50,000,000 gallons per day. The Soviets indicate that the Schevchenko Plant will be made up of modules or units, each capable of converting 5 to 6 million gallons of water per day.[43]

Control of the desalination program is currently under the State Committee for Utilization of Atomic Energy. Prior to 1962 it fell under the State Committee for Chemistry, but the move apparently was made to speed developments by elevating the national status of the program, and it also reflects Soviet intentions to develop the use of nuclear power sources for desalination purposes.

APPENDIX A

PRINCIPAL SOVIET INSTITUTIONS INVOLVED IN DESALINATION

Distillation

All-Union Heat Technology Institute imeni Dzerzhinsky, Leninskaya, Sloboda 23, Moscow, Zh-68.

Azerbaydzhan Order of Labor Red Banner Institute of Petroleum and Chemistry imeni M. Azizbekov, Prospekt Lenina 20, Baku. The Institute is subordinate to the Ministry of Higher Education, USSR.

Baku State Regional Electric Power Station, Severnaya (Gras Severnaya).

Kharkov Engineering and Economics Institute (Kharkovskiy Inzhenerno Ekonomicheskiy Institut), KhIEI, Prospekt Lenina 9, Kharkov.

Moscow Technological Institute of Light Industry (Moskovskiy Tekhnologicheskiy Institut Legkoy Promyshhlennosti), Ulitsa Osipenko 33, Moscow Zh-127.

Moscow Power Engineering Institute (Moskovskiy Energeticheskiy Institut, (formerly Imeni Molotov), Ulitsa Krasnokazarmennaya 14, Moscow YE-250.

Scientific Research Institute of Chemical Machine Building, Sverdlovsk Branch (Sverdlovskiy Filial Niikhimmash). This is possibly the same facility as the Sverdlovsk Machinery Construction Technicum, which is located at Ulitsa Chernyakhovskovo 32e, near the Ural Chemical Machine Plant.

Chemical Methods

All-Union Scientific Research Institute of Water Supply, Sewerage, Hydraulic Structures, and Engineering Hydrogeology (Vsesoyuznyy Nauchno-Issledovatel'skiy Institut Vodosnabzheniya, Kanalizatsii, Gidrolekhnecheskikh Sooruzheniy i Inzhenernoy Gidrogeologii), VODGEO. Prospekt Komsomolskiy 42, Moscow. This is one of the more important institutes doing desalting research and development.

Institute of Chemistry (Institut Khimicheskikh Nauk) IKhN, Ulitsa Kosmonavtor 85, Alma Ata. Visited by US Desalination Exchange

delegation in November 1964. This Institute is subordinate to the Academy of Sciences, Kazakh SSR.

Scientific Research Institute of Plastics (Nauchno-Issledovatel'-skiy Institut Plasticheskikh Mass) NIIPM, Prospekt Perovskiy 41, Moscow. The Institute is responsible to the State Committee for Chemistry.

Electrodialysis

All-Union Scientific Research Institute for Electrification of Agriculture, VIESKH. This Institute is located at the Plyushchevo R. R. Station in Moscow.

Moscow Aviation Technological Institute (Moskovskiy Aviatsionnyy Tekhnologicheskiy Institut), MATI, Petrovka 27, Moscow. The Institute is subordinate to the Ministry of Higher Education of the USSR.

Moscow "Order of Lenin" Institute of Chemical Technology imeni D. I. Mendeleyeva (Moskovskiy Ordena Lenina Khimiko-Teknologicheskiy Institut Im. D. I. Mendeleyeva), MKHTI, Ploschad Miusskaya 9, Moscow, D-47.

Other Methods

Moscow Institute of Water Economy Engineers imeni V. R. Vilyams (Moskovskiy Institut Inzhenerov Vodnogo Khozyastva imeni V. R. Vilyamsa), MIIVKh, Ulitsa Pryanisnikova 19, Moscow. This Institute also referred to as the water management engineers or hydraulic engineers institute.

APPENDIX B

PRINCIPAL SOVIET SCIENTISTS INVOLVED IN DESALINATION

Distillation

Alkazin, P. A.
Apel' tsin, I. E.
Brdlik, P. M.
Chernozobov (fnu)
Durov, S. A.
Dykhno, A. Yu.
Fedotov, K. V.
Golub, A. M.
Isachenko, V. P.
Ivanov, (fnu)
Khaliyev, N. P.
Klyachko, V. A.
Kot, A. Ya.
Krasikov, Ya. N.
Leventon, O. L.
Martynova, O. I.
Mirkis, I. M.
Noyev, V. N.
Novikov, I. I.
Radvinskiy (fnu)
Ravich, M. B.
Reznikov, M. I.
Romm (fnu)
Fosenberg (fnu)
Shatsillo, O. I.
Styrikovich, M. A.
Tkach, V. M.
Tronev, B. G.
Vainberg, P. B.
Vol'fkovich, S. I.
Zaostrovskiy, F. P.
Zenkovich, V. P.

Ion Exchange And Electrodialysis

Besman, V. L.
Fashko, I. L.
Gurvich, S. M.
Klyachko, V. A.
Makinskiy, I. Z.
Mamet, A. M.
Laskorin, B. W.
Lebedeva, N. S.
Lenchevskiy, O. S.
Losev, I. P.
Lyubman, N. L.
Orzherovskiy, M. A.
Pashkov, A. B.
Prokhorov, F. G.
Saldadze, K. M.
Shemyakin, O. N.
Shostak, F. T.
Simonov, P. P.
Tevlina, A. S.
Titov, V. S.
Trostyanskaya, Ye. B.
Ushakov, L. D.
Yankovskiy, K. A.
Zlotnikov, A. B.

Other Methods

Apel'tsin, I. E.
Gasanova, P. M.
Geller, S. Iv.
Lugovskiy, M. V.
Medvedev, I. N.
Pavlov, G. D.

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